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THE MORPHOLOGY AND PARASITISM OF RHIZOCTONIA

BY

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THE first reference to *Rhizoctonia* was made by Duhamel(9)*, who, in 1728, described a disease of saffron (*Crocus sativus*). He considered the sclerotia to be a special plant of which the hyphæ were the roots, and named the plant *Tuberoides*. In 1782 Fougeroux de Bondaroy(3) noted that asparagus which grew in the same field as saffron might become infected with this disease. The first attempt, however, to give the fungus a systematic position was made by P. Bulliard(4) who referred it to the Truffles under the name of *Tuber parasiticum*. Shortly afterwards it was placed by Persoon(21) in the genus *Sclerotium* and called *Sclerotium crocorum*. The name *Rhizoctonia* was first used by de Candolle(5) to describe a fungus on lucerne; ultimately he distinguished three species, *R. Crocorum*, *R. Medicaginis* and *R. Mali*. Nees(20) in 1817 also refers to a fungus attacking crocus as *Thanatophytum crocorum*; from an inspection of his figures there can be no doubt that this is *Rhizoctonia*. A few years later Duby(8) discovered *R. Allii* on *Allium ascalonicum*, and in 1843 Léveillé(18) described *Rhizoctonia* as attacking *Rubia tinctorum*, *Solanum tuberosum*, *Phaseolus*, and other plants; it is not, however, stated to what species of *Rhizoctonia* the attack was due. In 1851 Tulasne(28) united the known forms of *Rhizoctonia* into one species which he called *R. violacea*. This classification has since been adopted by many writers; Saccardo even includes *R. Solani* Kühn, in addition to *R. Medicaginis* D.C., under *R. violacea* Tul, but in view of the critical work of Kühn a few years later it

* The figures in brackets refer to the bibliography at the end of the paper.

would seem better to maintain the distinction between *R. Solani* and *R. Medicaginis*.

Of the earlier accounts of *Rhizoctonia* the best is that of Kühn(16) published in 1858. He mentions three species of Rhizoctonia—*R. Solani*, *R. Medicaginis* and *R. Crocorum*,—and gives a short account of sclerotial formation on the potato, contrasting the smooth sclerotia of *R. Solani* with the woolly sclerotia of *R. Medicaginis*; in addition to lucerne *R. Medicaginis* is also stated to attack beet and carrot. Kühn describes *Rhizoctonia* as producing a reddish brown colour in the cells of beet; he also gives figures of the hyphæ showing the characteristic mode of branching and the conjugation of cells. This is the first record of the appearance of the fungus in Germany, all the previous attacks having been in France; from now onwards the disease appears to have spread rapidly in Europe. In Denmark, between the years 1886 and 1902, it is recorded on numerous hosts, *e.g.*, carrots, lucerne, clover, sugar-beet and roots of beech, pine and larch. In Sweden the parasitism of the fungus has been recently investigated by Eriksson.(11) His experiments were directed chiefly towards the discovery of biologic forms of the fungus and showed that there was considerable variability in the susceptibility of different varieties of the carrot to the disease. The fungus which attacked the carrot would also attack the beet, though more virulently in the second generation, thus showing an increased adaptation to the new host. In England Güssow(14) has described the disease on potato and lucerne—he considers that *R. Solani* and *R. violacea* are one and the same.

In America *Rhizoctonia* is known to attack much the same crops as in Europe. Duggar and Stewart(10) have described it on a number of hosts; they do not, however, give any details about sclerotia, but confine themselves to a description of the vegetative hyphæ, and it is, therefore, impossible to determine from their account whether one or several species of *Rhizoctonia* occurred on the different hosts. The most interesting of the American publications on *Rhizoctonia* is that of Rolfs(24) who describes the morphology and parasitism of a species of *Rhizoctonia* on potato. A fruiting stage

was discovered and stated to be a basidiomycete already known to science as *Corticium vagum B. & C.* A basidiomycete is not, however, the only fruiting stage which has been attributed to *Rhizoctonia.* Fuckel(13) in 1869 stated that the ascomycete *Byssothecium circinans* Fkl. (*Leptosphæria circinans* Sacc.) was the perfect form of *Rhizoctonia;* both were found on decaying stems of *Medicago sativa,* but beyond this association there was no evidence of their connection with one another. Prunet(23) also observed this association of *Rhizoctonia* on lucerne with an ascomycete, but the absence of details of culture work lessens the value of his statements. Hartig(15) found a fungus resembling *Rhizoctonia* together with a *Rosellinia* on the roots of oak, and it has been suggested by Massee(19) that *Rosellinia* is the fruiting stage of *Rhizoctonia.* In 1897 Frank(12) reported *Rhizoctonia violacea* as attacking grape vines, a *Thelephora* was also found associated with it and named *Th. Rhizoctoniæ.* There are, therefore, three or four distinct fungi described as the fruiting stage of *Rhizoctonia* and some doubt still prevails as to which is the true perfect form.

In addition to the usual European hosts it seems fairly certain that *Rhizoctonia* in America attacks seedling cotton. In 1892 Atkinson(1) described a sterile fungus causing a damping off of cotton seedlings, and his description of the hyphæ of this fungus agrees very closely with *Rhizoctonia.* A similar disease known as "Sore shin" has been described in Egypt by Balls(2), who states that it is identical with that described by Atkinson but does not identify it as *Rhizoctonia.* A description of the *Rhizoctonia* attacking cotton in India is given below and a comparison renders it extremely probable that the American, Egyptian and Indian diseases are identical.

In Europe and America *Rhizoctonia* is widely distributed, the following being some of its more important hosts—

Sugar-Beet	*Beta vulgaris.*
Bean	*Phaseolus.*
Carrot	*Daucus Carota.*
Cabbage	*Brassica oleracea.*
Cotton	*Gossypium hirsutum.*
Lettuce	*Lactuca sativa.*

Potato	*Solanum tuberosum.*
Radish	*Raphanus sativus.*
Sweet Potato	*Ipomœa Batatas.*
Pumpkin	*Cucurbita Pepo.*
Water Melon	*Citrullus vulgaris.*
Garden Pea	*Pisum sativum.*
Lucerne	*Medicago sativa.*

The fungus frequently attacks the host in the seedling stage, and the similarity to the damping off caused by *Pythium* renders it not improbable that many cases of disease have been wrongly attributed to the latter genus. In India *Rhizoctonia* appears to have a wide range of hosts; in the past year the following plants were attacked on Pusa Farm—

Ground nut	*Arachis hypogœa.*
Cow Pea	*Vigna Catiang.*
Jute	*Corchorus capsularis.*
Soy Bean	*Glycine Soja.*
Dolichos Lablab	
Trichosanthes cucumerina	
Mulberry	*Morus alba.*

It has also been found on ground nut and sesame at Surat, on melon roots at Peshawar, on cotton at Cawnpore and on roots of *Agave rigida* in Madras. Some fifteen years ago Cunningham (7) described a root rot of lucerne and a disease of potato stems known as "Bangle blight," both of which he attributed to the attack of a sclerotial fungus. Judging from his description and figures, the fungus was most probably *R. Solani* Kühn, but in his memoir it was not identified. The fact that a disease of potato tubers due to the attack of *R. Solani* Kühn is known to occur in Bankipore strengthens this view.

In the rains of 1910 a severe outbreak of the disease took place on Pusa Farm, and the present research was undertaken to discover what species of the fungus was present in India and whether any specialisation existed in its parasitism on different hosts. The association of a basidiomycete resembling *Corticium vagum* with the *Rhizoctonia* also gave a favourable opportunity for investigating the connection between the two. The most important crops attacked were ground nut, cow pea, jute and cotton, and it was

with reference to these four hosts that the existence of physiological races of the fungus was investigated. As it became evident in the course of the research that more than one species of *Rhizoctonia* was present, it will be convenient to consider the results in two parts.

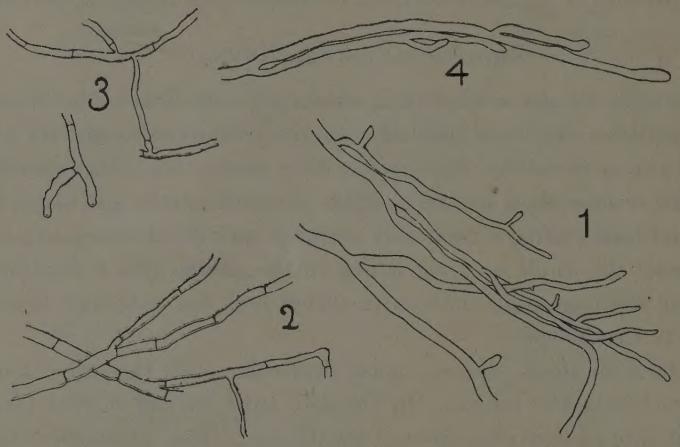
Rhizoctonia solani, Kühn.

Jute.—Rhizoctonia has been known for some time as the cause of a destructive disease of seedling jute, the symptoms being very similar to those caused by *Pythium* in other plants. Seedlings attacked by the disease show at first a slight yellowish patch just above the ground level; after a time this darkens and the tissues soften and collapse, the whole seedling falling to the ground (Pl. I, Figs. 3, 4). Young seedlings from one to two inches high are extremely susceptible to the disease.

In some cases plants a good deal older than this were found infected with the fungus. In October 1910, several mature plants in the jute plot at Pusa showed the disease; these plants were from 6 to 8 feet high and could easily be distinguished from their healthy companions by their withered leaves and blackened stems, the blackening being most marked at the base near the ground level. In 1911 the jute was sown on a different area, which had been left fallow during the previous season; there was very little disease in the crop and only a few infected plants could be found. One of these is shown in Pl. I, Fig. 1; the blackened infected area at the base of the stem is clearly visible. In a transverse section through this region the whole of the outer tissues of the stem appear rotted and broken down and in some cases hyphæ can be seen entering the wood (Pl. XI, Fig. 2); sclerotia occur in the decaying cortex. From diseased plants, such as these, cultures were obtained on agar medium E (see Appendix) and produced first a growth of white hyphæ and then numerous small black sclerotia.

In the jute districts of Eastern Bengal *Rhizoctonia* causes a certain amount of damage. Mature plants infected with the fungus have been collected in both the Mymensingh and Rangpur districts. In some years the damage to the seedling crop is extensive in certain

areas. The disease is also known on the Government Farm at Lyallpur in the Punjab and doubtless occurs to a certain extent wherever jute is grown.



TEXT FIG. I.—R. SOLANI KÜHN × 250.

The morphological characters of the fungus appear to vary with the age of the culture. In a sub-culture 24 hours old the hyphæ present the appearance shown in Text Fig. I, 1 ; the branching is abundant, the young branches are at first bent parallel to the main axis; all show that constriction at the base which is characteristic of *Rhizoctonia ;* at this stage transverse walls are very few, the wall which separates a branch from its parent hypha is usually about 15μ from the point of origin of the branch. The hyphæ are about 8—9μ in diameter and the cells from 50—150μ long. In a culture ten days old the upper surface of the agar is covered with a weft of white hyphæ and numerous black sclerotia are embedded in the agar. Under the microscope the aërial hyphæ appear of a blackish colour; they show the characteristic *Rhizoctonia* branching (Text Fig. I, 2), and the larger are from 6—8μ in diameter but the majority are very much finer; the sclerotia when mature appear as dark, black-rounded bodies about 100—150μ in diameter. In old cultures large hyphæ consisting of short barrel-shaped cells are plentiful.

On agar medium D the sclerotia have a brownish colour and are not formed quite so abundantly while on agar medium A they are much more scattered and the growth is altogether restricted. Cultures on carrot, potato, bread, meal and filter papers all gave sclerotia and hyphæ similar to those on agar; a fruiting stage was never obtained.

The fungus was found to attack seedling jute very vigorously, about 70% of the plants infected being killed. The symptoms and manner of death were as described above. Examination of the diseased seedlings showed hyphæ ramifying in all directions in the tissues of the host; these hyphæ (Text Fig. I, 3) resemble in all respects those in agar culture. By incubating a diseased seedling in a sterile petri dish a growth of white hyphæ was obtained which gave typical sclerotia when subcultured on agar. The vitality of the fungus in culture is considerable, cultures having been found living after five or six months.

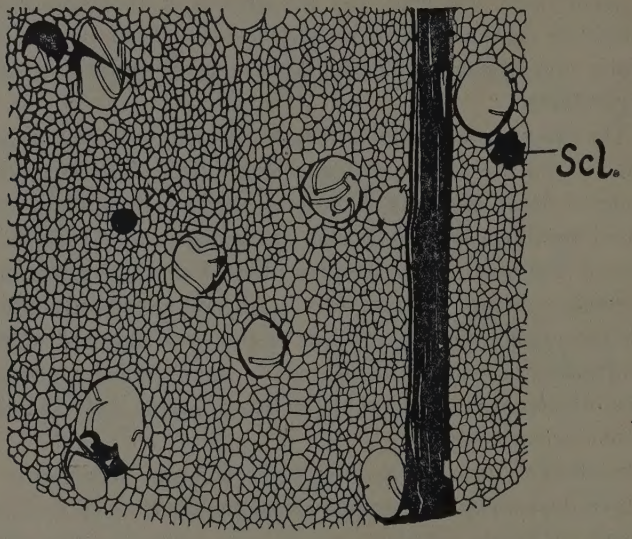
In all the culture experiments the soil was sterilised in steam for three days and placed in pots which had been carefully washed in corrosive sublimate solution. Seeds were washed in formalin solution (2·5%) for ten minutes and then sown, the pots were covered with bell jars as soon as germination took place; unless otherwise stated, infections were made by placing a small piece of agar culture on the stems.

Experiment I.—JUTE.

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	REMARKS.
1	25-2-11	15	..	..	Control.
2	,,	15	7-2-11	12	Plants died in about three days.
3	,,	100	,,	60	Culture spread on top of soil, not laid on plants.

A fungus exactly similar to the *Rhizoctonia* of jute has been found attacking the mulberry, Text Fig. I, 4; shows its appearance in an agar culture 24 hours old. The attack takes place at the base of the plant the whole of the bark and phlœm being destroyed; in

some cases the decayed area completely rings the stem and abundant sclerotia are formed in the wood (Text Fig. II). At this stage the

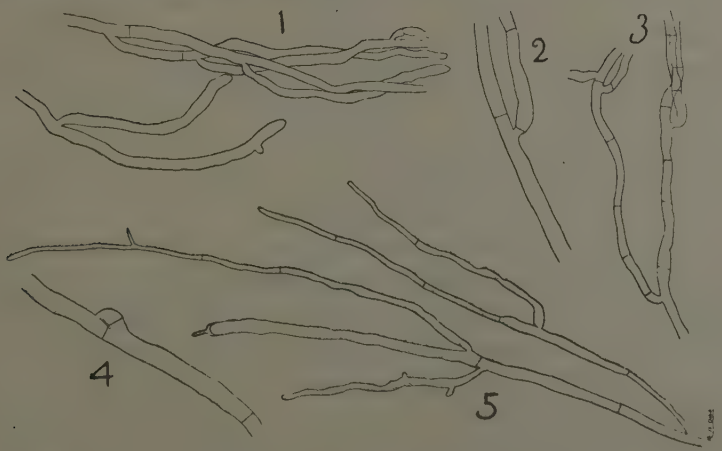


TEXT FIG. II.—R. SOLANI KÜHN.

disease resembles very strongly the "Bangle Blight" of potato (Cunningham (7) Pl. I, Fig. 9, 10). Infections upon jute seedlings gave a mortality of 80% of infected plants; infections upon the mulberry did not give any decisive results. Plants which were infected in July lived until November, when both infected and uninfected plants died owing to the cold weather. Examination of the former, however, showed that the fungus had destroyed the phlœm and was penetrating the wood at the seat of infection.

Cotton.—In June 1911 a disease of cotton occurred on the Cawnpore Farm. Specimens of infected seedlings sent from Cawnpore had a soft yellow patch on the lower portion of the hypocotyl (Pl. IV, Fig. 1), and in bad cases the rot was sufficient to cause collapse of the seedling. Microscopic examination revealed the presence in the rotted area of numerous *Rhizoctonia*-like hyphæ which grew in all directions from the pith to the cortex; sclerotia were not present.

The disease caused some loss among the experimental plants of the Economic Botanist. It was more or less restricted to pot cultures of special varieties and did not attack *desi* cotton in the field. The attack was of brief duration but nearly all the pots showed diseased plants; some of the plants attacked recovered and in this case a dry brown spot persisted on the stem. A second attack on the same plant never takes place. The seedlings seem to be susceptible only when quite young; by the time they are planted out in the field there is no danger of attack; thus deaths were plentiful at the commencement, but ceased after the first few days when seedlings were too old to be attacked. Towards the close of the outbreak several completely withered and diseased seedlings were collected. They all showed hyphæ of *Rhizoctonia* and in one case sclerotia were found on a blackened area at the base of the hypocotyl (cf. Jute seedling, Pl. I, Fig. 1). The sclerotia (Pl. VIII, Fig. 1, Pl. IX, Fig. 2) were rounded bodies, exactly like the sclerotia on jute but rather smaller, the average diameter being about 90μ. The diameter of the hyphæ varied from 6—10μ. Separate cultures were obtained from sclerotia and hyphæ; in both cases the result was a *Rhizoctonia* exactly resembling that on jute. Text Fig. III, 1, shows



TEXT FIG. III.—R. SOLANI KÜHN × 250.

hyphæ in an agar culture 24 hours old and Text Fig. III, 2, 3 represents hyphæ from diseased seedlings. In culture on agar medium E the sclerotia reach a larger size than on the cotton seedlings, some of them being as much as 150μ in diameter.

I have not been able to consult in the original Atkinson's description of the sterile fungus attacking cotton in America, but Balls quotes Atkinson's description as follows :—

"The freshly developed threads branch freely, but not profusely ; they are colourless, composed of elongated cells 9—11μ in diameter, and 100—200μ in length. The branches very near the point of attachment are a little curved towards the point of growth of the same. At the point of attachment with the parent hypha, the branch is considerably smaller than either the diameter of the parent hyphæ or the main part of the branch, and the septum separating the protoplasm of the greater part of the branch from that of the parent hypha, is situated some distance from the latter, usually 15—20μ from the main thread. This portion of the branch, the contents of which are continuous with the parent thread, is clavate in form."

Other American authors evidently consider this disease to be due to *Rhizoctonia ;* thus Duggar and Stewart (10) include it in their paper under the heading "*Rhizoctonia* in America," and Stevens and Hall(27) give "rhizoctoniose" as a synonym for "sore shin." A comparison of the above description with that of the fungus which has just been described as attacking jute and cotton shows a substantial agreement in all essential points. Atkinson's measurements seem to be slightly larger, but it has already been mentioned that the size of the hyphæ varies with the age of the culture.

Balls states that Atkinson's description applies equally well to the Egyptian "sore shin" fungus ; it follows therefore that in America, Egypt and India cotton is attacked by *Rhizoctonia.* The symptoms of "sore shin" disease agree exactly with those of the present outbreak, but Balls did not obtain any of the sclerotia which occur so abundantly in our cultures and which are mentioned by Atkinson. The only reproductive organs which he mentions are termed "resting cells," and are stated to arise by the enlargement

of certain hyphæ which become segmented into barrel-shaped cells. Hyphæ such as these occur in our cultures but are nearly always an early stage in the formation of a sclerotium (Pl. VII, Figs. 1, 2, 3); in some cases similar hyphæ are plentiful in older cultures.

According to Balls(2) a medium consisting of filter papers in 2% solution of asparagin or cane-sugar is most suitable for the formation of "resting cells." Cultures of the *Rhizoctonia* of ground nut on filter paper moistened with a solution of lactic acid and nutrient salts (see Appendix) gave rise to hyphæ with sclerotia consisting of large loosely connected cells (Pl. VIII, Figs. 2, 3). In cultures of the *Rhizoctonia* of cotton on filter paper moistened with 2% cane-sugar or asparagin similar structures were formed.

Inoculations in the laboratory gave different results according to the variety of cotton infected. While *Rhizoctonia* does not attack *desi* cotton in the field, it caused a mortality of 20—30% in the experiment detailed below. In the case of another variety of cotton known as "khaki" the mortality reached as high as 90 per cent.

Experiment II.—"DESI" SEED.

Pot.	Date of sowing	No. of plants in pot.	Date of infection.	Deaths.	REMARKS.
1	1-7-11	5	..	..	Control.
2	,,	3	6-7-11	..	....
3	,,	3	,,	..	....
4	,,	3	,,	2	Plants died 14 days after infection.
5	4-7-11	6	9-7-11	..	Infected with young culture.
6	,,	5	,,	2	
7	,,	5	,,	1	Infected with old culture.
8	,,	5	,,	2	

Experiment III.—"KHAKI" SEED.

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	REMARKS.
9	11-7-11	6	17-7-11	5	Isolated *Rhizoctonia* from one of the diseased plants.
10	,,	3	,,	..	Control.
11	,,	4	,,	..	
12	,,	2	,,	..	

Ground nut.—In the beginning of 1911, while examining some seeds of ground nut, it was noticed that in a large number of seeds the pericarp had a mottled appearance, showing discoloured patches (Pl. IV, Figs. 3, 4). Examination of these dark areas revealed, in some cases, hyphæ, like those of *Rhizoctonia*, ramifying in the tissues ; in other cases there was no apparent cause for the discoloration. Not only were hyphæ found in the pericarp but they were also sometimes present within the embryo. Portions of the pericarp of seeds, and, in some cases, entire seeds, were incubated in sterile petri dishes and gave a vigorous growth of hyphæ of *Rhizoctonia* which was sub-cultured on agar medium E.

A further experiment was then performed in which four seeds were sterilised by soaking in 2·5% Formalin for five minutes, and sown in sterile drying towers containing Knop's solution, a method first used by Ward(29). Of these four seeds only one germinated, the remaining three died and became covered with an abundant growth of hyphæ and small black sclerotia, which were sub-cultured on agar medium E ; the cultures obtained in this way resembled those of the *Rhizoctonia* of cotton and jute. Later in the year, in August, an examination of the ground nut crop on Pusa Farm showed that many plants were infected with *Rhizoctonia*. The upper portion of infected plants appears brown and withered (Pl. III, Fig. 3), while at the ground level the stem is a dark black colour ; in this portion hyphæ and sclerotia are particularly abundant. Specimens of ground nut attacked by *Rhizoctonia* were also received from Surat ; in these the small black sclerotia were abundant, occurring not only on stems but also on leaves. A small piece of one of these blackened stems was incubated and gave a culture which resembled in all respects that obtained from the hyphæ in the seeds. In this connection it may be noted here that specimens of diseased sesame from Surat were found to be infected with *Rhizoctonia* in the same way as the ground nut, the external symptoms of the disease and the cultural characters of the fungus exactly resembling those detailed above.

Further proof that the ground nut seed may be infected with *Rhizoctonia* was afforded by the behaviour of the plant in pot culture. Out of all the cultures of the jute, cotton, cow pea and ground nut made in the course of this research, it was only in the case of ground nut that deaths due to *Rhizoctonia* infection took place in the control pots. If the deaths in the control pots had been due to soil infection, owing to imperfect sterilisation, it would be expected that similar deaths would also take place in the cultures of jute, which is far more susceptible to the attack of *Rhizoctonia* than is ground nut. Moreover, the ground nut ripens its seeds below the surface of the ground in the same situation as those tubers (potato, carrot, etc.) which are often badly attacked by *Rhizoctonia*.

The morphological features of the *Rhizoctonia* of ground nut agree exactly with those of cotton and jute. The characteristics of the hyphæ in an agar culture 24 hours old are shown in Text Fig. III, 5; in the case of some diseased plants from Peshawar hyphæ with clamp connections were present (Text Fig. III, 4). The manner of the formation of the sclerotia was studied and is shown in Pl. VII, Figs. 1, 2, 3, & 4. In a hypha which is about to form a sclerotium a large number of transverse divisions take place, so that a number of short barrel-shaped cells are formed which are very rich in oil globules. Some of these give rise to lateral outgrowths, consisting of one or two cells, which grow parallel with, and adhere to, the side of the parent hypha. By the constant repetition of this process a mass of parenchymatous cells is formed which eventually becomes the mature sclerotium (Pl. IX, Figs. 1, 2); there is some slight differentiation into cortex and medulla, the central cells being large and thin-walled, while the peripheral cells have a smaller lumen and thicker walls. This process agrees closely with that described by Kühn for sclerotial formation in *R. Solani*.

Culture work on the ground nut was complicated by the liability to sow infected seed. On the whole, about 30% of the inoculations were successful. In a successful inoculation the stem turns

brown at the point of infection and numerous black sclerotia are formed. If the ground nut were first wounded, the percentage of deaths reached as high as fifty ; this plant also seemed peculiarly susceptible to attack at the growing point.

Experiment IV.—Ground nut (Pusa seed).

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	17-5-11	5	..	..	Control.
2	,,	4	27-5-11	1	Plants become rotted at point
3	,,	4	Wounded & infected. 29-5-11	1	of infection just above ground level, abundant hyphæ and sclerotia formed.
4	,,	5	25-5-11	2	..
5	,,	4	Wounded & infected. 12-6-11	1	Infected near growing point.
6	,,	6	12-6-11	2	

Cow pea.—The symptoms of attack in this case are the same as those already described for the ground nut, and the fungus also resembles that of the other three hosts (Pl. IX, Fig. 1). Inoculations upon the cow pea produce abundant sclerotia (Pl. II, Fig. 3) ; as in the ground nut, the growing point seems peculiarly liable to infection. In the early stages of infection a red brown discoloration appears upon the stem and slowly spreads, the stem ultimately becomes flaccid and collapses. Sclerotia are formed abundantly. A portion of a diseased stem was incubated and gave a vigorous growth of *Rhizoctonia*. Infections from agar cultures on unwounded plants gave an average mortality of 50% ; if the plants had been previously wounded at the point of infection the mortality sometimes reached as high as 80% of the infections. In one pot the plants were infected with a piece of a diseased plant from another pot, and it was noticeable that in this case the virulence of the fungus seemed to be less than in the previous experiments, only one infection out of six proving fatal.

Experiment V.—Cow pea (Pusa seed).

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	8-3-11	7	17-3-11	3	Infection usually shows sign of taking after 4 or 7 days, but sometimes death not complete for 6 weeks.
2	„	3	20-3-11	2	....
3	„	6	Wounded & infected 25-3-11	3	In one plant which was infected at the base—the hyphæ grew right up in the stem and formed abundant sclerotia on the growing point.
4	„	5	Wounded & infected 25-3-11	4	....
5	17-5-11	6	11-6-11	4	Infection with culture from Cow pea seeds not agar.
6	17-5-11	6	29-5-11	1	Infected with piece of stem containing sclerotia from dead plant of pot 2.
7	8-3-11	7	..	..	Control.

Cross inoculations.

Eriksson(11) investigated the parasitism of *Rhizoctonia* on carrots, beet-root and other European hosts, and found that the susceptibility of carrot to the attack of *Rhizoctonia* varied according to the variety of carrot infected. He was able to make the *Rhizoctonia* pass from the carrot to the beet. Its virulence upon beet, however, was greatly increased after being parasitic upon that plant for one generation, thus showing a gradual adaptation to the new host; clover, which is sometimes attacked in Denmark, he was not able to infect with this *Rhizoctonia*. Eriksson's results show therefore a very slight specialisation in the parasitism on different hosts.

In the case of the four crops dealt with in this research the results agree more or less with those of Eriksson. In three of the hosts, namely, ground nut, cotton and cow pea the infection powers of the respective *Rhizoctonias* seem to be of a like order. In each case the fungus isolated from any one host will infect the other two,

although its virulence is greatest on its own particular host. Thus the *Rhizoctonia* from cotton if infected upon ground nut, jute or cow pea has a mortality of about 40—50%, but upon cotton it has a mortality of 80%.

The behaviour of the jute plant and its *Rhizoctonia* is, however, rather different. Jute is attacked very vigorously by its own *Rhizoctonia*, the mortality rarely falling below 70% of infected plants. *Rhizoctonia* of cotton and ground nut is considerably less virulent on jute, the infective power of the latter being much higher if the jute be first wounded. This applies in an even greater degree to the *Rhizoctonia* of cow pea, which does not attack uninjured jute at all but has a mortality of 50% on wounded jute.

The *Rhizoctonia* of jute shows a high degree of specialisation as it does not, under normal circumstances, attack the other three hosts at all. Both on *desi* and "khaki" cotton and wounded and unwounded cow pea infections failed to take. In the latter plant the host successfully reacted to the attack by cork formation round the infected area (Pl. VI, Fig. 2); in cotton the hyphæ seemed unable to penetrate the epidermis and the plant was not injured in any way. In the early stages of attack on the cow pea the hyphæ are more or less intercellular in growth. In those cases in which the plant reacts successfully against the fungus (*e.g.*, attack of the *Rhizoctonia* of jute) the hyphæ appear to remain in this state (Pl. VI, Fig. 2) ; should, however, the *Rhizoctonia* prove fatal, intracellular hyphæ are speedily formed (Pl. VI, Fig. 1).

Infections which were made on ground nut early in the year failed to give any result, but on repeating the experiment four months later death resulted in the case of one infection. The ground nut seed in this case, however, was not above suspicion ; at the same time the fact must not be overlooked that after nearly a year in culture the infective powers of a fungus may change. On the whole, considering all the facts with regard to the *Rhizoctonia* of jute, it seems clear that we have to do here with a physiological specialisation unaccompanied by any outward morphological distinction. Details of the experimental work are shown opposite on page 131

Experiment VI.—Rhizoctonia of jute on cow pea—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	17-2-11	6	..	..	Control.
2	,,	6	Wound infection 28-2-11	..	Plant reacted against attack of fungus by cork formation.
3	29-5-11	8	..	..	Control.
4	,,	5	5-6-11	..	No trace of infection after 5 weeks.
5	8-3-11	7	21-3-11	..	....

Experiment VII.—Rhizoctonia of jute on cotton (*desi* seed). In this experiment the seed was germinated on moist blotting paper in petri dishes and afterwards planted—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	20-8-11	6	..	..	Control.
2	,,	6	..	..	,,
3	,,	7	25-8-11	..	No attack.
1	2-6-11	6	..	..	Control.
2	,,	5	6-6-11	..	No attack.

Experiment VIII.—Rhizoctonia of jute on cotton ("khaki" seed). The seed was germinated in petri dishes as in Exp. VII—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	16-8-11	6	..	1 (?)	Control.
2	,,	5	25-8-11	3 (?)	All the deaths were due to attack by *Fusarium*.
3	,,	3	..	..	Control.

Pot.	Date of sowings.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	16-9-11	5	21-9-11	..	Infection did not take.
2	,,	6	,,	..	,,
3	,,	4	..	..	Control—one death due to *Fusarium*.
4	,,	4	..	1 (?)	
5	,,	3	..	..	

Experiment IX.—Infection of *Rhizoctonia* of jute on ground nut—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	6-3-11	6	..	..	Control.
2	,,	6	21-3-11 3 Wound infections	..	..
			3 Infections without wounds	..	..
3	27-7-11	7	Infected hypocotyl and root 7-8-11	2—3	..
4	,,	6	Wounded & infected hypocotyl & root 7-8-11	1—3	..
5	,,	4	..	3	Control.
6	,,	5	..	1	

In the case of the plants in Pot 3 it is very probable that the deaths were due to infected seed. All the diseased plants developed *Rhizoctonia* in the root at the seat of infection, but one also showed a copious growth of *Rhizoctonia* at the apex where there had been no infection; the intermediate portion of the stem was quite healthy and did not contain any hyphæ. In Pot 4 only one plant developed *Rhizoctonia* at the seat of infection, the other two plants developed it at the apex. In the control pots two of the deaths in Pot 5 were due to the development of *Rhizoctonia* at the apex, and one to an attack at the base of the hypocotyl; the death in Pot 6 was also due to an attack at the base of the hypocotyl.

Experiment X.—*Rhizoctonia* of cotton on jute—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	25-7-11	8	..	..	Control.
2	,,	8	..	..	,,
3	,,	11	3-7-11	2	Deaths took place from 2 to 7 days after infection.
4	,,	8	,,	6	Incubation of diseased plant gave *Rhizoctonia*.

Experiment XI.—Rhizoctonia of cotton on cow pea—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	11-7-11	5	17-7-11	4	....
2	,,	6	..	..	Control.
3	5-8-11	1	..	..	
4	,,	2	..	..	
5	,,	1	..	..	
6	,,	4	Wounded and infected 10-8-11	2	....

Sclerotia were not formed so abundantly on diseased plants as in other cases. The stems became reddish brown and soft at the point of attack. hyphæ were numerous running in all directions through the cells. Infections were made both at the growing point and on the hypocotyl; in one of the former sclerotia were formed (Pl. IV, Fig. 2).

Experiment XII.—Rhizoctonia of cotton on ground nut (small Japan)—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	20-6-11	6	..	..	Control.
2	,,	6	3-7-11	1	Infection made at the apex, which became covered with sclerotia, none of the ground level infections took.
3	,,	6	,,	..	
4	,,	6	,,	..	
5	27-7-11	6	Infected stem & root 7-8-11	2	..
6	,,	4	Wounded and infected stem & root 7-8-11	4	..
7	,,	4	..	2	Control.
8	,,	5	..	1	

In Pot V the plants developed *Rhizoctonia* at the apex and not at the base, where they had been infected. In three of the plants in Pot 6 the *Rhizoctonia* was developed at the place of infection, the whole of the hypocotyl becoming rotted with abundant formation

of sclerotia ; in the remaining plant the apex became attacked. The diseased plants in the control pots were attacked both at the apex and the base. It is impossible to say whether all the cases of death were due to infected seed, the three deaths in Pot 6 may be due to *Rhizoctonia* of cotton. At all events it appears from Pot 2 that *Rhizoctonia* of cotton can attack ground nut.

Experiment XIII.—Rhizoctonia of ground nut on jute—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	17-5-11	8	23-5-11	6	Wounded & infected.
2	,,	14	,,	3	Infected without wound.
3	,,	8	,,	..	Wounded not infected.
4	,,	8	..	..	Control.

Experiment XIV.—Rhizoctonia of ground nut on cotton (*desi* seed)—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	2-6-11	6	..	..	Control.
2	,,	6	5-6-11	..	Sclerotia and hyphæ developed, obtained pure culture on incubating diseased plants, 4-7-11.
3	,,	6	,,	2	
4	16-6-11	4	..	..	Wounded not infected.
5	,,	6	20-6-11	1	Wounded and infected. One death due to *Rhizoctonia*.
6	20-8-11	6	..	..	Control.
7	,,	6	..	..	
8	,,	6	25-8-11	..	

Experiment XV.—Rhizoctonia of ground nut on cotton ("khaki" seed)—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	16-8-11	6	..	..	Control.
2	,,	6	25-8-11	..	Infection did not take.
3	,,	3	..	..	Control.

Rhizoctonia of ground nut is slightly parasitic on cotton.

Experiment XVI.—Rhizoctonia of ground nut on cow pea—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	17-5-11	7	23-5-11	3	Sclerotia formed abundantly, incubated diseased plants and obtained culture of *Rhizoctonia*.
2	„	8	23-5-11	3	
3	„	6	..	..	Control.
4	29-5-11	8	..	..	
5	„	6	5-6-11	..	

Infections take more readily at the apex than at the base.

Experiment XVII.—Rhizoctonia of cow pea on jute—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	25-2-11	9	17-3-11	..	Infected without wounding.
2	„	9	„	4	Wounded and infected.
3	„	9	..	..	Control.

Experiment XVIII.—Rhizoctonia of cow pea on cotton ("khaki")—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	1-8-11	4	8-8-11	3	Incubated diseased plants and obtained culture of *Rhizoctonia*.
2	„	1	Wounded and infected, 8-8-11	1	
3	„	4	..	..	Control.
4	„	2	..	..	Wounded not infected.
5	„	4	Wounded and infected, 10-8-11	2	

Experiment XIX.—Rhizoctonia of cow pea on ground nut—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
1	6-3-11	6	..	1	Control pot not kept under a bell jar—one death due to *Rhizoctonia*.
2	,,	6	..	..	
3	,,	6	28-3-11	..	
4	,,	6	Wounded and infected, 27-3-11	2	*Rhizoctonia* developed in tissues at point of infection.

It is difficult to be certain from the results of this experiment whether the *Rhizoctonia* of cow pea is really parasitic on ground nut. In a further experiment the seeds were germinated under conditions, which rendered chance infection practically impossible ; under these circumstances the appearance of the disease could only result from deliberate inoculation or from the use of infected seed. Five carefully selected seeds were sown on cotton-wool in sterile drying towers containing Knop's solution ; all the seeds germinated, but only three produced healthy young seedlings. One of these was inoculated at the apex and also just below the cotyledon with *Rhizoctonia* of cow pea. This plant very soon died with an abundant development of *Rhizoctonia* in the infected areas (Pl. III, Fig. 1).

The following table shows at a glance the infective powers of the different varieties of *Rhizoctonia*, the numbers refer to the percentage of inoculations which proved fatal—

Ground nut.		Jute.	Cow pea.	Cotton.		Remarks.
Pusa seed.	Small Japan.	14—72	42	Desi.	Khaki.	*Rhizoctonia of ground nut.*
30	..	..	..	16	No result.	
16	5	50 Inoculations failed to take unless the plant was first wounded.	50—80	..	60—70	*Rhizoctonia of cow pea.*
..	16	40	50—80	20—30	90	*Rhizoctonia of cotton.*
No result.		60—80	No result.		No result.	*Rhizoctonia of jute.*

In cases where the figures show a wide variation in the mortality the higher number refers to inoculations made upon plants which had been first wounded.

The variety of ground nut referred to as "small Japan" was obtained from Bombay in the hope of getting seed free from infection.

Preventive measures.

Rhizoctonia is essentially a soil fungus attacking the subterranean portions of plants and passing over unfavourable periods by means of its sclerotia. Any method of treating the disease should have therefore as its first objective the destruction of the sclerotia in the soil. To do this on a large scale is an operation of some difficulty and expense, and is not a proceeding which is likely to commend itself to the Indian cultivator. Probably the best means of combating the disease is by a careful rotation of crops; up to the present there does not appear to be any record of *Rhizoctonia* attacking a cereal crop, and such crops might be grown with safety in fields, where more susceptible plants would be destroyed. It is not exactly known how long the fungus can perennate in the soil. Prunet (23) mentions three years as the time during which a field might remain infectious.

In the case of cotton Balls (2) has found a seed-dressing of naphthaline beneficial in the treatment of the disease. If used in the right proportion the vapour of naphthaline does not injure the germination and is sufficient to kill or inhibit the growth of the fungus during the early stages when the seedling is liable to attack.

Eriksson's experiments indicated that treatment of the soil with carbolic acid might be a preventive for the disease and further work by Salmon (25) has confirmed this. The solution used was 1 oz. of phenol to 1 gallon of water, and about 40 gallons were applied by means of a watering pot to a plot of land 19 feet by 9 feet.

Some experiments made in Pusa seem to show that carbolic powder is capable of protecting jute from the attack of *Rhizoctonia*; careful research is, however, necessary in order that the germination of the seed may not be injured by the disinfectant—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Remarks.
1	14-8-11	15	Soil not infected with Rhizoctonia.	7 seeds germinated and formed healthy plants.
2 soil treated with carbolic ..	,,	,,		11 do. do. do.
3 soil treated with naphthaline ..	,,	,,	..	No germination.
4	,,	,,	..	11 seeds germinated, all seedlings killed.
5 soil treated with carbolic ..	,,	,,	Fungus spread in soil with seed.	7 seeds germinated and formed healthy plants.
6 soil treated with naphthaline ..	,,	,,	..	No germination.

From the above table it will be seen that jute seed is very sensitive to naphthaline. Methods, such as this, which aim at destroying the fungus in the soil, must be distinguished from others, which merely ensure the planting of clean seeds. In the case of tubers (*e.g.*, potato), and plants (*e.g.*, ground nut) which ripen their seed below the ground level, some means of disinfecting diseased seed should be adopted. Rolfs (24) found that treatment of diseased potato seed with corrosive sublimate or formalin considerably improved the outturn ; this method, however, must be combined with suitable and systematic rotation in order to give the best results.

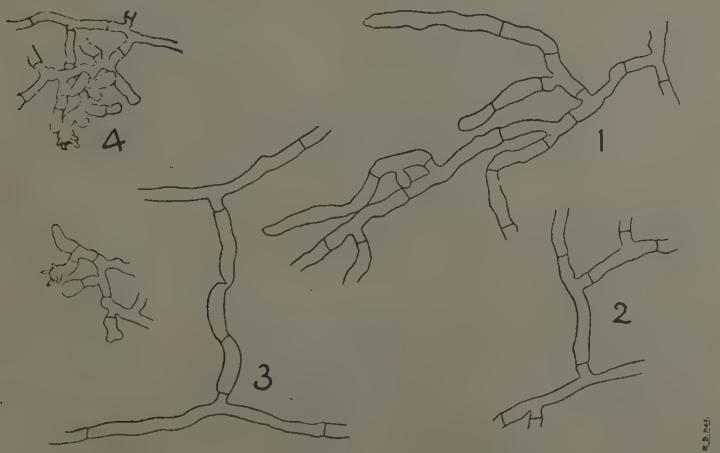
Identity of the fungus.

The commonest species of *Rhizoctonia* appears to be *R. violacea* Tul., under which name Saccardo includes *R. Medicaginis* D. C. and *R. Solani* Kühn. Kühn gives a careful description of these two forms and states that the principal difference between them lies in the sclerotium ; in both cases this is a small round black structure, but that of *R. Solani* is smooth while that of *R. Medicaginis* is covered with hyphæ. A comparison of Fig. 1, Pl. IX, in this paper with Taf. VII, Fig. 21 of Kühn shows the essential similarity between the sclerotium of *R. Solani* and that of the form described above ; moreover, the sclerotial fungus which occurs on potato

tubers at Bankipore is morphologically indistinguishable from that which has just been described on jute, cotton, ground nut and cow pea. Under these circumstances it seems better to identify the *Rhizoctonia* which attacks these four crops as *R. Solani* Kühn than either as *R. Medicaginis* D. C., or the rather indefinite *R. violaceæ* Tul. It may be noted here that Eriksson refers to the *Rhizoctonia* on carrot as *R. violacea*, and in his figures the sclerotia appear as small black dots like those on the cow pea (Pl. II, Fig. 3); *R. Medicaginis* is, however, described as attacking the carrot and Eriksson's fungus was probably this. It is impossible to tell from the description of Cunningham (7) whether the sclerotial fungus which he describes as attacking lucerne in India was *R. Solani* or *R. Medicaginis*.

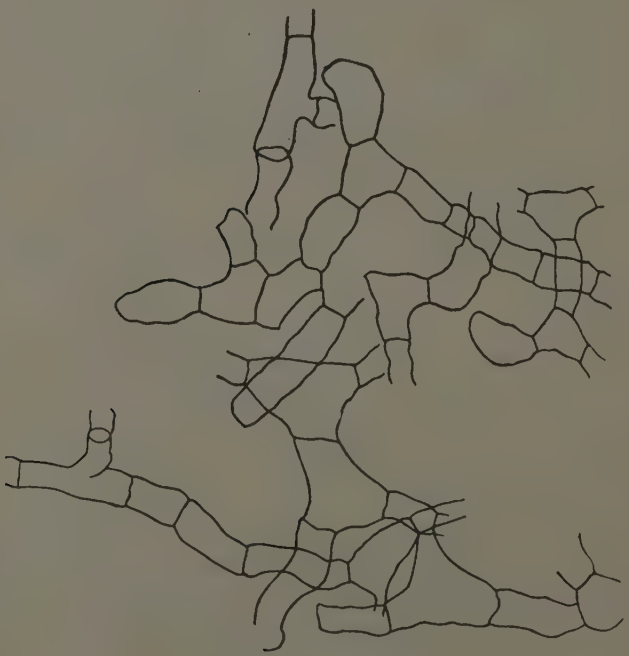
Corticium vagum B. & C.

In October and November 1910, and also in 1911, a form of *Rhizoctonia* which differed considerably from the above was found attacking the ground nut and cow pea. Diseased plants were brown and withered at the infected spots, and usually bore several sclerotia, which were much larger than the sclerotia of *R. Solani*, the size varying from 1-5 mm. (Pl. V, Figs. 1, 2).



Text Fig. IV Corticium Vagum B. & C. × 250.

The hyphæ of the fungus to which these sclerotia belong resembled strongly those of the *R. Solani* attacking jute, cotton, &c. The cells were from 6-10μ in diameter and from 100-200μ long, the branches all showed the basal constriction and disposition of the transverse wall which is characteristic of *Rhizoctonia* (Text Fig. IV, 1); conjugation between cells of different hyphæ sometimes takes place (Text Fig. IV, 3). There was some variation in the size of the cells, but not so much as in the case of the *Rhizoctonia* of jute. The very fine hyphæ which occur in cultures of the latter are not present here; in old cultures the hyphæ turn a reddish brown colour. Mature hyphæ often present the curious appearance shown in (Text Fig. V), the cells being of triangular shape; this is usually an early stage in the formation of a sclerotium (cf. Rolfs Pl. V, Fig. 2, Bull. 91). Young sclerotia are visible to the naked eye as fluffy aggrega-



TEXT FIG. V. × 500.

tions of hyphæ. They are at first quite white, but later the colour changes to brown, and they become hard and compact. The mature sclerotium is very different to that of *R. Solani* Kühn. It can easily be seen that it consists of interwoven hyphæ (Fig. 1, Pl. XI), the structure is uniform throughout, and there is complete absence of any differentiation into cortex and medulla. These large sclerotia are much more obviously composed of pseudo-parenchyma than are the small ones of *R. Solani*.

In some diseased ground nut plants certain leaves were coated on the surface with a white layer (Pl. V, Fig. 3). Examination of this layer showed it to be composed of closely interwoven hyphæ, which were obviously *Rhizoctonia* hyphæ. In some parts of the leaf, where this layer was most marked, the lateral branches of the hyphæ were very numerous and peculiar. These branches were short club-shaped structures with a transverse wall some distance from the point of origin, their swollen club-shaped ends often bore from two to four finger-like processes, each of which carried a single spore: they were in fact basidia bearing four sterigmata (Text Fig. IV, 4). The spores are hyaline oval structures about 12-10 by 8-6μ (Pl. X, Figs. 3, 4, 5). This form of fructification was found on the cow pea (Pl. V, Fig. 4,), and on *Trichosanthes*, in addition to the ground nut; on all three plants hyphæ and sclerotia of the type just described were present. Hyphæ are abundant in the tissues of leaves which bear the basidial layer. Infections upon cow pea and ground nut showed that the fungus was a virulent parasite upon both these plants. Seedlings of cow pea were infected both near the growing point and on the hypocotyl, the former taking the more vigorously. The infected area rapidly turns a reddish brown colour, as described in the case of *R. Solani*, and the tissue becomes soft, the whole plant finally collapsing (Pl. IV, Fig. 5).

In the case of the ground nut, mature plants, bearing nuts, were taken from the field and placed in pots. Infections upon the leaves gave rise, at first, to a white growth of hyphæ, which formed later both sclerotia and the characteristic fruiting layer. Hyphæ subsequently spread all over the plant, which gradually turned a

deep brown colour; death was slow in the case of a mature plant of ground nut. The infections were made in each case with hyphæ from an agar culture which had been originally infected with a sclerotium; this sclerotium was obtained from a culture made by infecting an agar tube with a scraping of basidia. The connection between basidia and sclerotia is, therefore, established.

Infection on the cow pea—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
I	19-10-11	4	..	..	Control.
II	„	3	27-10-11	3	*Rhizoctonia* hyphæ abundant in diseased tissue.

Infection on the ground nut.—

Pot.	Date of sowing.	No. of plants in pot.	Date of infection.	Deaths.	Remarks.
I	Taken from field and potted 24-10-11	1	..	..	Control.
II					
III		1	..	..	
IV		1	30-10-11	2	Sclerotia and basidia formed on plants.
		1			

It was found to be impossible to get the perfect stage into culture on artificial media. It is apparently strictly parasitic. On the living plant it forms a close network on the surface of stem and leaves, and when the spores have been shed it wears off. In the field the development of basidia is particularly vigorous on those leaves which are well shaded and in moist damp situations.

Cultures on agar (media B, C, D, E, F, G), all produced abundant white hyphæ and sclerotia. This happened both in the case of tubes infected with sclerotia and in those infected with a scraping from the fertile layer. Cultures upon filter paper, pith moistened with extract of ground nuts and corn meal also gave the same results.

In addition to the evidence from inoculations other facts all go to prove that the perfect form of *Rhizoctonia* is a basidiomycete such as we have described.

In the first place, this basidiomycete has been associated with the same sclerotia and hyphæ for two successive years on three different hosts, and moreover it agrees in every particular with that described by Rolfs as attacking potatoes in America; Rolfs identifies it as *Corticium vagum* B. & C. The evidence which he gives for regarding it as the fertile stage of *Rhizoctonia* is—

(1) association of basidia and sclerotia on same host;

(2) cultures obtained by germinating spores on agar had the typical characteristics of *Rhizoctonia;*

(3) infection of sclerotia and *Rhizoctonia* hyphæ on living plants gave rise to the fruiting layer.

Rolf's description of the sclerotia and hyphæ which are connected with the *Corticium* stage agrees in all essentials with that given above (cf. Rolfs' Bull. 91, Pl. I and Pl. V with Pl. V, Fig. 3 and Text Fig. V), and does not resemble the *R. Solani* Kühn described in the earlier portion of this memoir.

Further evidence of the organic connection between these sclerotia and hyphæ and the basidiomycete is furnished by a paper by Stevens and Hall (26) entitled "Hypochnose of Pomaceous Fruits." These authors describe a fungus, attacking apple, pear and quince, which has all the characteristics of *Rhizoctonia*. The hyphæ have the typical *Rhizoctonia* appearance (Fig. 5, Stevens and Hall), while the following description of the sclerotia would serve equally well for those on ground nut or cow pea—

"A section of the sclerotia reveals them as compactly woven masses of swollen irregular hyphæ. They are entirely devoid of any special epidermal structure, false epidermis or rind, the peripheral structure being identical with the interior."

The account of the sporogenous stage agrees closely with that of the basidiomycete on the ground nut.

Stevens and Hall identify their fungus as *Hypochnus ochroleucus* Noack, they do not make any mention of the similarity of the hyphæ and sclerotia to those of *Rhizoctonia*. A comparison of their paper, however, with that of Rolfs, and with the present memoir

can leave no doubt as to the identity of the fungus on apple with that on potato and ground nut.

It is difficult to say whether *Hypochnus* or *Corticium* is the genus to which this fructification should be referred. Clinton (6) first suggested that "the *Corticium* stage is the same fungus described by Prillieux and Delacroix as *Hypochnus Solani*." Rolfs, however, investigated this matter and concluding that *Corticium vagum* B. & C. more nearly represented the fungus, he named it *C. vagum* B. & C. var. *Solani*. In a review of this paper Laubert (17) revived the suggestion that the fruiting stage is not *Corticium vagum*, but the nearly related *Hypochnus Solani*, which he described as occurring in connection with *Rhizoctonia* on *Melilotus alba*. The spore measurements given in this memoir agree closely with those of Rolfs; as, however, those of *Hypochnus ochroleucus* and *H. Solani* are much the same size, this point is hardly diagnostic. It seems not improbable that all three species are really only one fungus on different hosts; in this connection it is interesting to note that some writers doubt whether there is any distinction between *Hypochnus* and *Corticium*. On the whole, since the description of *Corticium vagum* by Berkeley and Curtis antedates that of *Hypochnus Solani* by Prillieux and Delacroix, we are inclined to accept Rolfs' identification.

There remains to be discussed the connection between the form of *Rhizoctonia* with large sclerotia, and a basidiomycete fruiting stage, and the *R. Solani* Kühn described in the first part of this memoir. In both cases the vegetative hyphæ are similar, but the sclerotia differ widely in origin, structure and size. Kühn in his original description of *R. Solani* makes no mention of the large sclerotia at all, and moreover in our cultures the two forms remained perfectly distinct for a year, behaving as separate species.

Rhizoctonia violacea Tul., however, is described (Prillieux 22) as possessing two distinct forms of sclerotia, microsclerotia, agreeing with the small black sclerotia identified in this memoir as *R. Solani* Kühn, and macrosclerotia, resembling the large brown sclerotia which occur in association with *Corticium vagum*. The species of *Rhizoctonia* which Rolfs (24) identifies as *R. Solani* Kühn possesses macro-

sclerotia, but there is no mention of microsclerotia in his paper. It is difficult to understand therefore on what grounds the American *Rhizoctonia* on potato can be identified as *R. Solani* Kühn. If both these sclerotia really belong to one fungus, then the creation of *R. violacea* Tul. as a collective species, possibly including *R. Solani* Kühn, would be justified ; the evidence contained in this paper, however, is decidedly against this view. Cultures and inoculations of the microsclerotia always gave microsclerotia, cultures and inoculations of macrosclerotia either produced macrosclerotia or the fertile *Corticium* stage. Additional evidence showing that the two sclerotia are really distinct is furnished by the work of Stevens and Hall and of Eriksson.

Stevens and Hall (26) describe macrosclerotia in association with the *Corticium* stage on the apple, but they do not make any mention of microsclerotia. Again, judging from the description and figures in Eriksson's paper, the fungus on carrot, which he considered to be *R. violacea*, possessed typical *Rhizoctonia* hyphæ and the small blackish brown microsclerotia, but here again there is no mention of macrosclerotia. Thus in two cases investigators working with one form have failed to mention the other, a fact which is hardly credible if the original conception of *R. violacea* is correct. In some cases (*e.g.*, ground nut and cow pea) both forms may occur on the same host, and indeed it was their association on the saffron which led Tulasne to attribute them to one fungus.

Assuming that two distinct fungi are present, and that the species *R. violacea* Tul., like many other botanical species, is a composite one, the question of the identity of the macrosclerotial form with any known species of *Rhizoctonia* remains to be settled. Certain points of resemblance were noticed between this form and *R. destruens* Tassi, which occurs on the roots of *Delphinium* in Italy, otherwise none of the known species seem to resemble it very closely. On the whole, perhaps the simplest and most convenient solution of the difficulty would be to retain the name *R. violacea* for the macrosclerotial form. While, therefore, the fertile stage of the macrosclerotial form is *Corticium vagum*, that of the microsclerotial, which

is identified here as *R. Solani* Kühn, has yet to be discovered. It is possible that *Rhizoctonia* is a form-genus in which are included the vegetative stages of widely separate fungi; if this is the case, there may yet be some truth in the observations of those investigators who have attributed other fructifications to this fungus.

APPENDIX.

Agar Medium A.—

Agar	15 grms.
Ammonium nitrate	10 „
Calcium sulphate	5 „
Magnesium sulphate	1 „
Lactic acid	2 „
Water	1,000 c.c.

Agar Medium B.—

Take 20 seeds of ground nut, grind them up in a mortar and boil with 150 c.c. of water for two hours, allow to stand for 24 hours, decant the supernatant liquid and filter, add water up to 500 c.c.

Agar	7·5 grms.
Aqueous extract of ground nut	500 c.c.

Agar Medium C.—

Take 5 prunes, extract the stones and boil the prunes in 100 c.c. water for 5 minutes, add water up to 500 c.c.

Agar	7·5 grms.
Extract of prunes	500 c.c.

Agar Medium D.—

Agar	15 grms.
Ammonium nitrate	10 „
Calcium sulphate	5 „
Magnesium sulphate	1 „
Glucose	20 „
Water	1,000 c.c.

Agar Medium E.—

Extract of Lemco	4 grms.
Sodium chloride	5 „
Peptone	10 „
Glucose	20 „
Agar	15 „
Water	1,000 c.c.

Agar Medium F.—

Take 50 grms. of finely ground French beans, boil with 10 c.c. of water for one hour, and filter through a wire gauze tea strainer. Add 10 grms. agar and water up to 500 c.c., boil and filter through linen cloth.

Agar Medium G.—

Boil 30 grms. of agar with 1 litre of water for 30 minutes, also 9 grms. Salep with 1 litre of water for 30 minutes. Mix the two together and add the following :—

1 grm. Grape sugar.
2 grms. Monopotassium phosphate.
Trace Ammonium nitrate.
„ „ sulphate.
„ Ferric sulphate.
„ Magnesium sulphate.
2 grms. Tartaric acid.

Boil for half an hour and filter in the steriliser (see Macé, E.—Traité pratique de Bacteriologie, Paris, 1889).

Filter Paper.—

Ammonium nitrate	10 grms.
Calcium sulphate	5 „
Magnesium sulphate	1 „
Lactic acid	2 „
Water	1,000 c.c.

Take 50 c.c. of the above solution, add 10 grms. filter paper and sterilise (see Küster, E.—Kultur der Mikroorganismen, 1907, p. 140).

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DESCRIPTION OF PLATES.

Plate I.

Fig. 1. Young jute plant from field infected with *R. Solani* Kühn*.

,, 2. Healthy seedling of jute.

Figs. 3, 4. Jute seedlings from pot culture inoculated with *R. Solani* Kühn.

Fig. 5. Leaf of cow pea attacked by macrosclerotial form of *Rhizoctonia*.

,, 6. Pod of cow pea from Pusa crop, attacked by macrosclerotial form, young sclerotia appear white, mature sclerotia are brown.

Plate II.

Fig. 1. Early stage in the infection of cow pea seedling with *R. Solani* Kühn.

,, 2. Later stage of same.

,, 3. Branch completely killed and covered with small black sclerotia.

,, 4. Normal plant.

Plate III.

Fig. 1. Ground nut seedling infected with *R. Solani* Kühn from cow pea, copious growth of hyphæ at the apex.

,, 2. Ground nut seedling killed by inoculation with *R. Solani* Kuhn at the apex, the diseased portion is covered with small black sclerotia.

,, 3. Ground nut plant from the field infected with *R. Solani* Kühn.

Plate IV

Fig. 1. Cotton seedling inoculated with *R. Solani* Kühn, the small dots on the stem are oil glands, sclerotia have not yet been formed.

,, 2. Cow pea seedling inoculated with *R. Solani* Kuhn from cotton plant—abundant sclerotial formation.

,, 3. Ground nut seed, healthy.

,, 4. Ground nut seed infected with *R. Solani* Kühn in pericarp.

,, 5. Cow pea seedling inoculated with macrosclerotial form of *Rhizoctonia*.

* Unless otherwise stated all figures are natural size.

Plate V.

Fig. 1. Two macrosclerotia of *Rhizoctonia* × 16.

„ 2. Leaf of ground nut attacked by *Rhizoctonia* (macrosclerotial form), the young sclerotia show as white fluffy masses, the mature sclerotia are more compact brown structures.

„ 3. Leaf of ground nut with two brown sclerotia of *Rhizoctonia* and the white fertile layer of *Corticium vagum*.

„ 4. Stem of the cow pea showing patches of the white sporogenous crust of *Corticium vagum*.

Plate VI.

Fig. 1. Transverse section of outer portion of cortex of a diseased plant of cow pea showing hyphæ of *R. Solani* in tissue. × 375.

„ 2. Transverse section of outer cortex of cow pea inoculated with jute *Rhizoctonia*, cork formation is taking place in the inner layers of the cortex. ph. = phellogen × 375.

Plate VII.

R. Solani Kühn.

Fig. 1. Hypha consisting of short barrel-shaped cells, an early stage in the formation of a sclerotium × 500.

„ 2. Later stage in the same × 1,000.

„ 3. Further stage showing adhesion of lateral branches to main axis × 500.

„ 4. Young sclerotium of *Rhizoctonia* of cotton. It is still possible to trace the course of the original parent hypha × 375.

Plate VIII.

R. Solani Kühn.

Fig. 1. Sclerotia and hyphæ of the cotton *Rhizoctonia* from an agar culture × 300.

Figs. 2, 3. Hyphæ from a culture made on filter paper in a solution of cane-sugar × 500.

Plate IX.

Fig. 1. Microphotograph. Transverse section of sclerotia of *R. Solani* Kühn on the cow pea, the disintegrated tissue of the host can be seen surrounding the sclerotia × 400.

2. Microphotograph. Transverse section of sclerotia of *R. Solani* Kühn on the cotton plant × 375.

Plate X.

Fig. 1. Hyphæ of *Rhizoctonia* (macrosclerotial form) from leaf of ground nut incubated in moist chamber for 24 hours × 500.

„ 2. Mature basidium with spores from leaf of ground nut × 1,000.

„ 3. Spores showing early stage of germination × 1,000.

Figs. 4, 5. Fertile basidia and spores from cow pea × 1,000.

Plate XI.

Fig. 1. Microphotograph. Transverse section of a macrosclerotium of *Rhizoctonia* × 62.

„ 2. Transverse section of stem of jute plant showing hyphæ penetrating the wood × 400.

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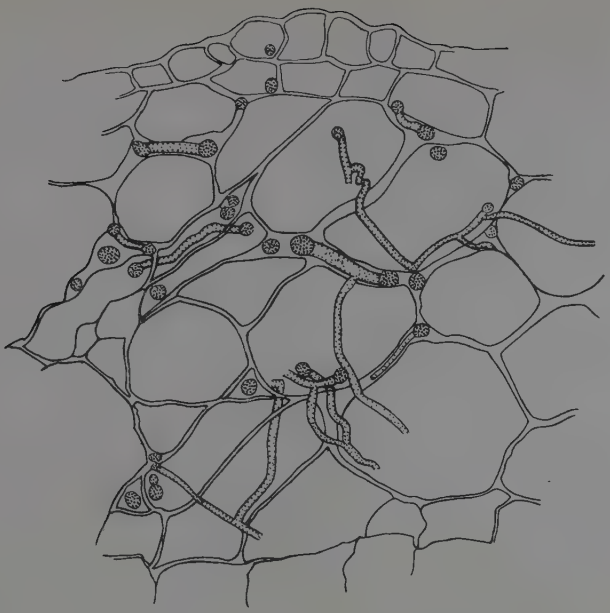
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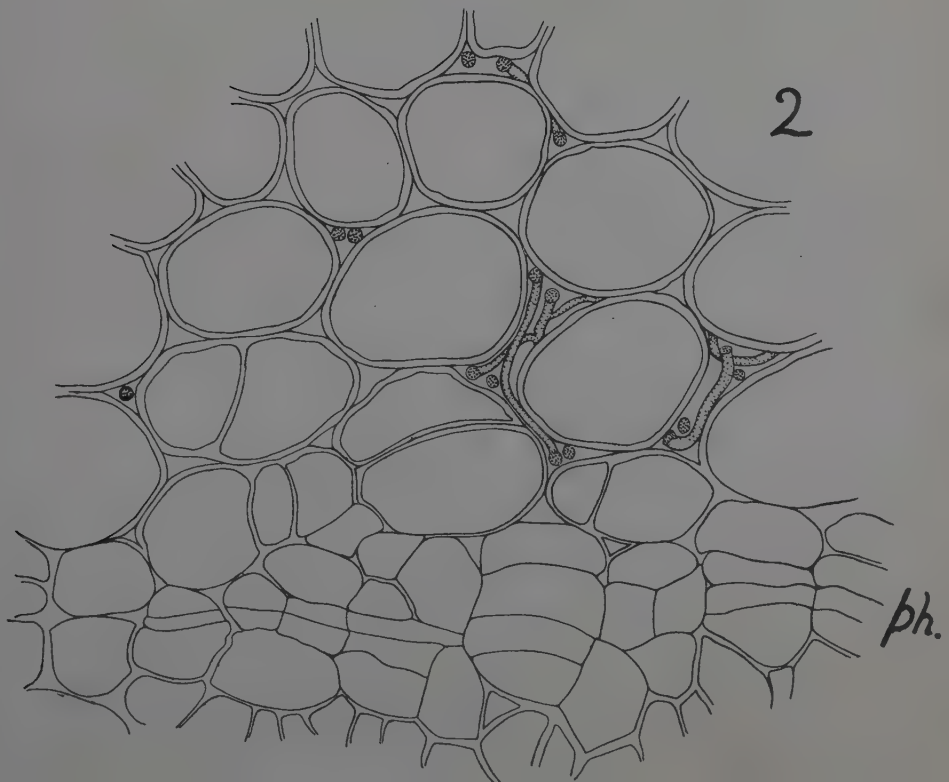
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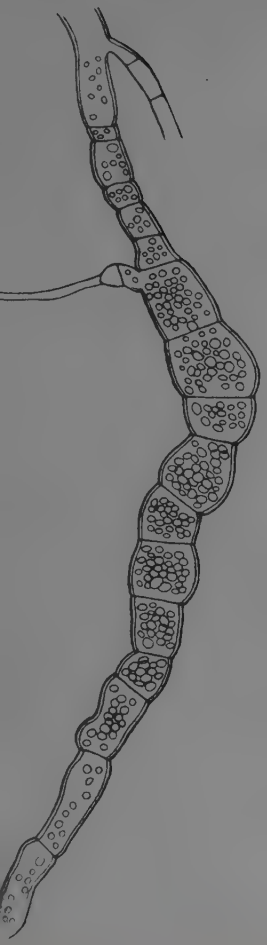

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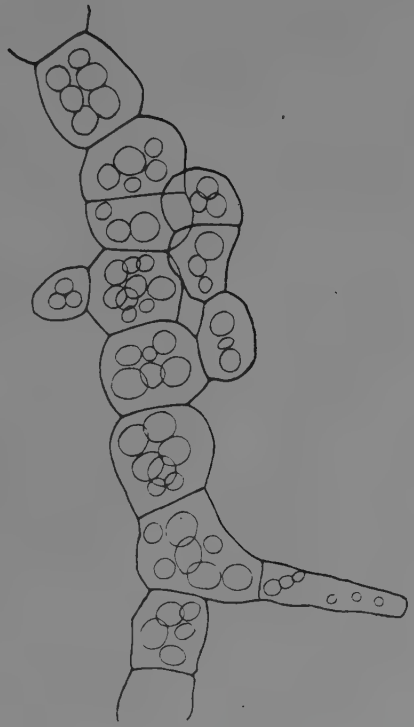

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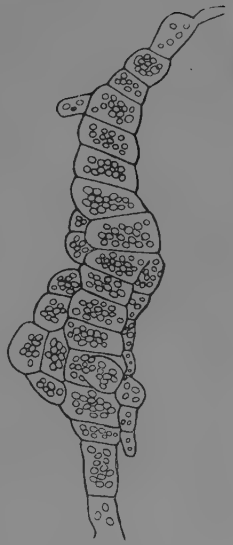

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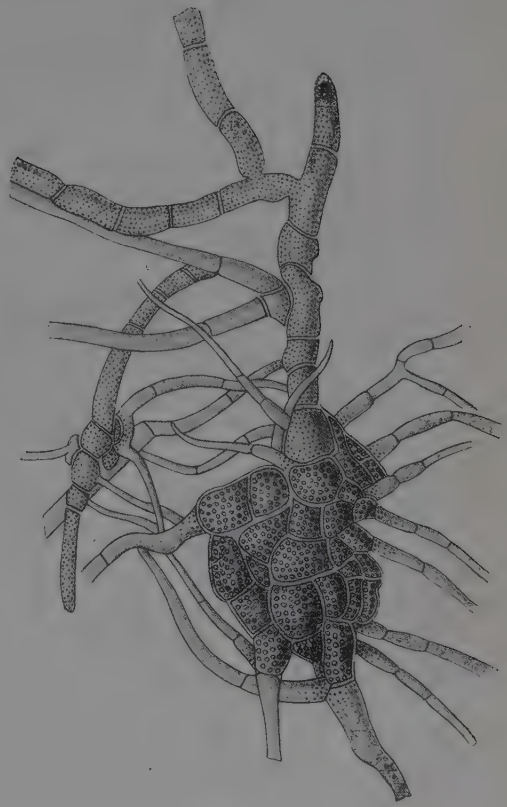

Fig. 4.

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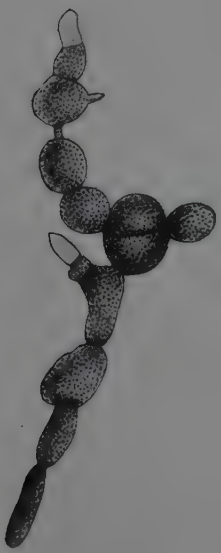

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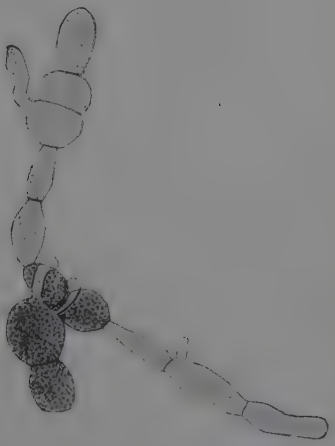

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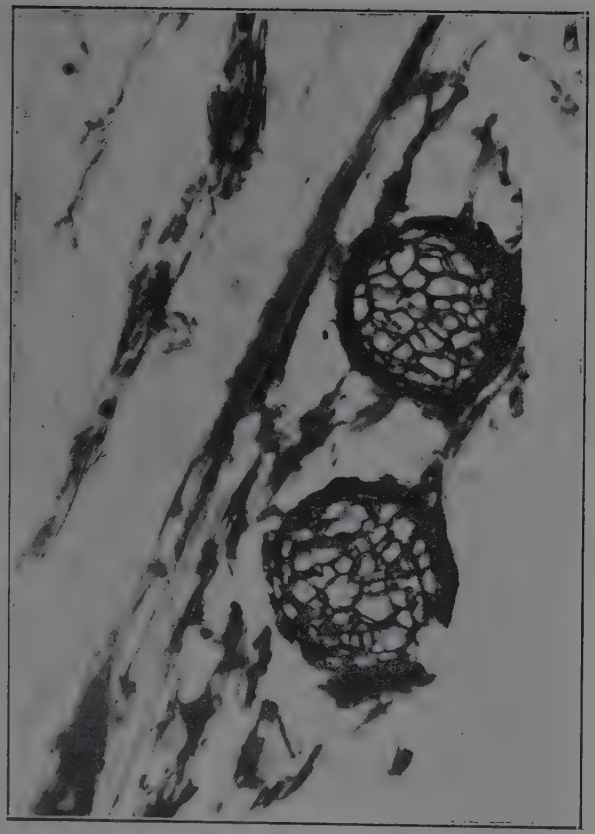
PLATE IX.



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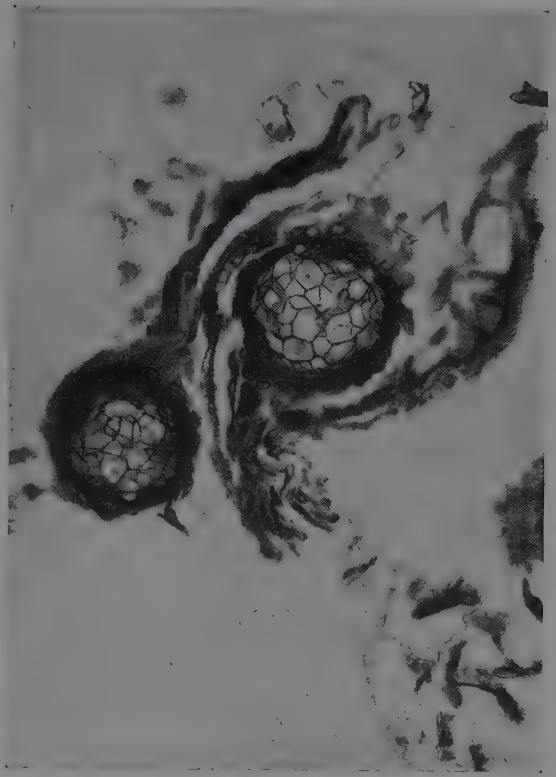
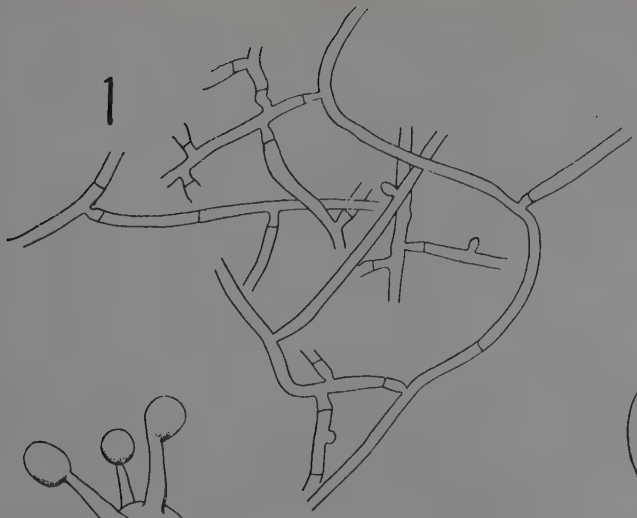
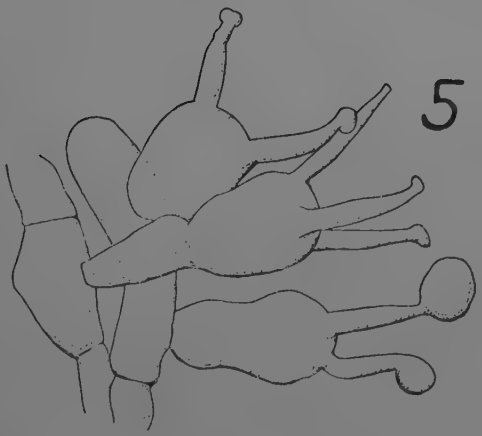


FIG. 2.

PLATE X.





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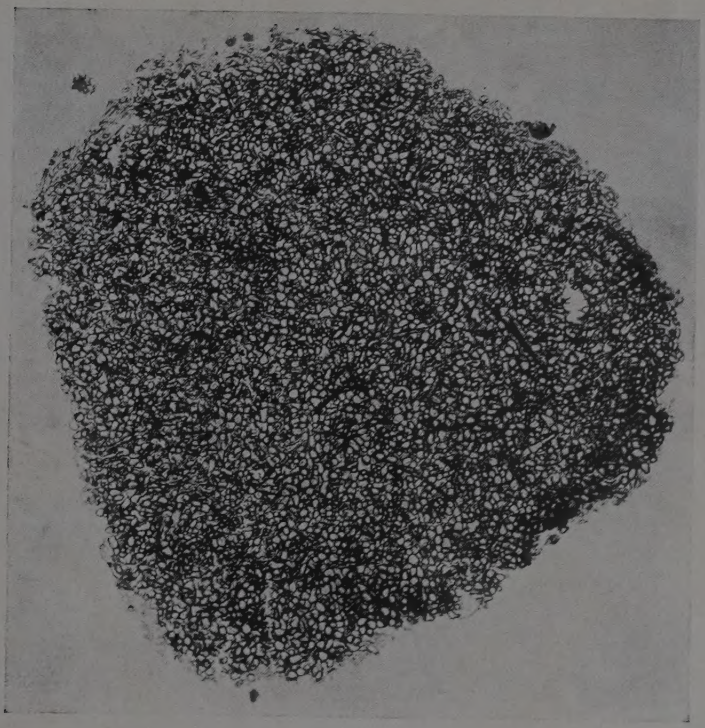

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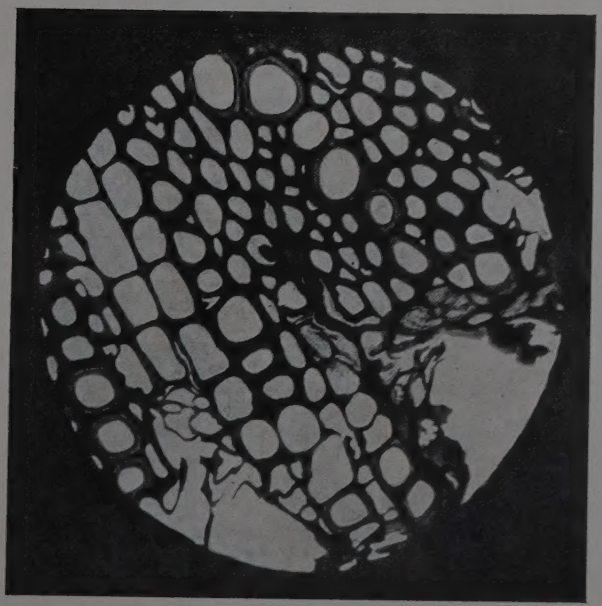

FIG. 2.